Sectoral Applications Research Program
Project Annual Report

Project Title: Creating Resilience to Climate Change: Cost-Effective Land Conservation in the Floodplain

Investigators:
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NOAA Grant Number: NA12OAR4310094

Project Years: 8/1/2012 – 7/31/2015 (with no-cost extension)

Time Period Addressed by Report: 5/1/2014 – 4/30/2015

I. Preliminary Materials

A. Research project objectives

To build resilience in the face of flood risk, many communities in the U.S. are focusing on floodplain conservation as a buffer against climate-induced increases in flooding. While interest in this approach is growing, many questions remain, particularly surrounding the economics of the approach. These unanswered questions hinder wider adoption of this policy. Our study area is St. Louis County, Missouri, a community that is located in the triangle formed by the Missouri, Mississippi, and Meramec Rivers and that faces serious flood risks. The project has three parts: (1) a retrospective analysis of the costs and benefits of the Meramec Greenway, a large land area along 108 miles of the Meramec River that has been targeted and set aside as protected land, primarily for flood mitigation purposes; (2) an assessment of projected changes in future flood damages in St. Louis County as a result of climate change; and (3) a prospective analysis of the role of strategically-placed green infrastructure in the Missouri and Mississippi River floodplains in mitigating increased flood risks from climate change. We will also include a study of the potential for transferring development from flood-prone areas to other areas in the county.

B. Stakeholders and decision-makers

- Great Rivers Greenway
- Association of State Floodplain Managers
- Missouri Department of Conservation
- East-West Gateway Council of Governments
- National Recreation and Park Association

C. Approach

This project has three research tasks: (1) a retrospective analysis of the costs and benefits of the Meramec Greenway in reducing flood damages and providing recreational and other co-benefits; (2) an assessment of projected changes in flood damages in St. Louis County associated with climate change; and (3) a prospective analysis of the role of land use change in mitigating increased flood risks from climate change, including a shifting of development away from at-risk areas.

The first task involved estimating flood damages in St. Louis County along the Meramec and its tributaries with the Greenway in place and then simulating what flood damages would be had the Greenway not been created and the area been developed instead. This difference in flood damages is an estimate of one benefit of the Greenway: avoided flood damages. The analysis also included estimation of recreational and other co-benefits and a comparison of total benefits with costs. The co-benefits proved to be large and total benefits greater than total costs.

To estimate flood damages, we used a GIS-based model developed for FEMA by the National Institute of Building Sciences called Hazus. To implement the flood module, Hazus relies on a Digital Elevation Model (DEM) to delineate a stream network. Once the network is created, Hazus invokes a hydrology and hydraulics model to generate a flood depth grid. For a given return period or discharge volume, this estimates the depth of the flood. For the loss module, Hazus draws from national databases of the inventory of structures and critical facilities at a census block level. Depth-damage curves, which link the depth of flooding to the amount of damage are coupled with the flood surface elevation layer to estimate physical damages. These vary by occupancy class and building materials.

We integrated data into our Hazus runs to improve estimation and resolution. In all our runs—both for the retrospective analysis of the Meramec Greenway and the prospective study we describe below—we upgraded the DEM to one with a 1/3 arc-second (10-meter) resolution, also from USGS. We also updated the inventory of structures using GIS parcel level data available from the St. Louis County Planning Department coupled with more detailed information on structures available from the St. Louis County Tax Assessor's office using Hazus's User Defined Facility (UDF) tool.

We estimated two important co-benefits of the greenway: recreational access and views of natural areas. We used St. Louis County property sales data from 1980 to the present and econometrically estimate a hedonic model which relates individual house sales prices to various house characteristics (such as square footage, lot size, and other factors), neighborhood characteristics, and then measures of proximity to the Greenway and measures of views (both extent and land cover in these views).

The second task of the project involved the creation of new flood depth grids for our study area to incorporate into the future climate change scenarios in task 3. This requires more sophisticated hydraulic modeling than is found in Hazus. Drs. Pinter and Reno led this effort. Hydraulic modeling was used to determine water surface elevations (WSELs) for possible change in future flood-discharges. This was done using a model from the U.S. Corps of Engineers. To estimate water surface elevations within overtopped or breached levees, levees were treated as lateral structures and storage areas. The output of this modeling was flood depth grids made in ArcGIS to be used in the third stage of the project. The hydrologists also conducted the same modeling assuming a 30% peak discharge increase, to simulate a future climate change scenario.

In the third task, we used the flood depth grids from task 2 to model damages under alternative flood scenarios, including climate change scenarios with higher peak discharges. We estimated flood damages with current land use and current flood risk, exploring alternative depth-damage relationships from the literature, and compare to damages under possible future flood risks. We analyzed alternative climate adaptation scenarios that involve land use change. Specifically, we assessed combinations of property buyouts and land conservation that yield damages under climate change that are equivalent to damages under current climate conditions. We estimated the costs of these alternatives and discussed other implications such as the locations and land uses of the targeted parcels.

D. Matching funds/activities

No matching funds are available but some activities have had synergistic benefits for this project. Kousky completed a draft paper for a project (funded by a National Science Foundation grant to the Colorado School of Mines) estimating whether and to what extent levee protection is capitalized into commercial property sales in St. Louis County. This has led to data analysis and research on the background of flood issues the county faces, which has been helpful for this project. Kousky has also had an on-going project (funded by the Keck Foundation) examining how wetland protection was treated in a series of U.S. Army Corps of Engineers cost-benefit analyses investigating flood protection options in New England watersheds. She has published an RFF discussion paper on this work. This has allowed for more careful thinking of how to estimate and evaluate the costs and benefits of floodplain conservation.

E. Partners

- Nicholas Pinter, Southern Illinois University
- Jonathan Remo, Southern Illinois University

II. Accomplishments since last progress report in May 2014

A. Project timeline and tasks accomplished

- Three peer-reviewed articles published (see below)
- Our research partner, Jonathan Remo of Southern Illinois University, decided to do additional flood modeling for St. Louis County. In addition to flood depth grids for the 100-year flood, we now have flood depth grids for the major rivers in the county for the 10-year, 50-year, and 500-year flood events. We have combined these results with flood depth grids from Hazus-MH for the smaller streams and tributaries in the region. These results allow us to calculate average annualized losses from the distribution of flood events, and not just losses from the 100-year flood. All of this flood modeling has been done for two scenarios: (i) today's climate and land use, (ii) a climate change scenario in which peak discharges are 30% higher than today.
- We are currently using the flood analysis to carry out our economic analysis of alternative buyout scenarios.
- We have completed a draft of a paper entitled "Climate Adaptation in the Floodplain: The Economics of Property Buyouts" (coauthors: Carolyn Kousky, Margaret Walls, Jonathan Remo and Jessica Chu) to be submitted to the peer-reviewed journal *Nature Climate Change.*
- Margaret Walls gave a presentation of the work to a graduate class at the University of Pennsylvania in April 2015.

B. Application of your findings to inform decision-making

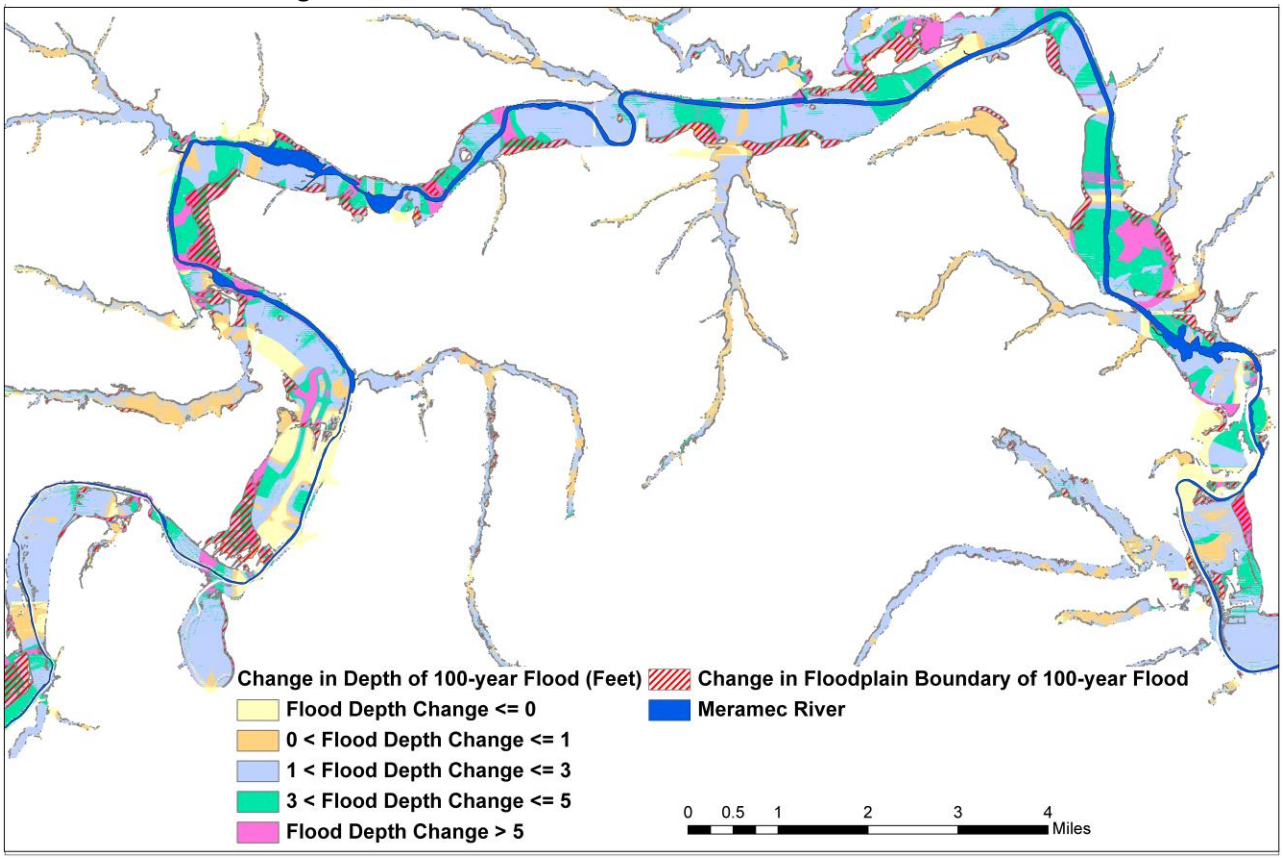
- Carolyn Kousky met with Great Rivers Greenway staff and invited representatives from the St. Louis region in September 2014.

C. Completed publications

- Margaret Walls, Carolyn Kousky, and Ziyan Chu, "Is What You See What You Get? The Value of Natural Landscape Views," *Land Economics* V91, no. 1 (February) 2015, pp 1-19.

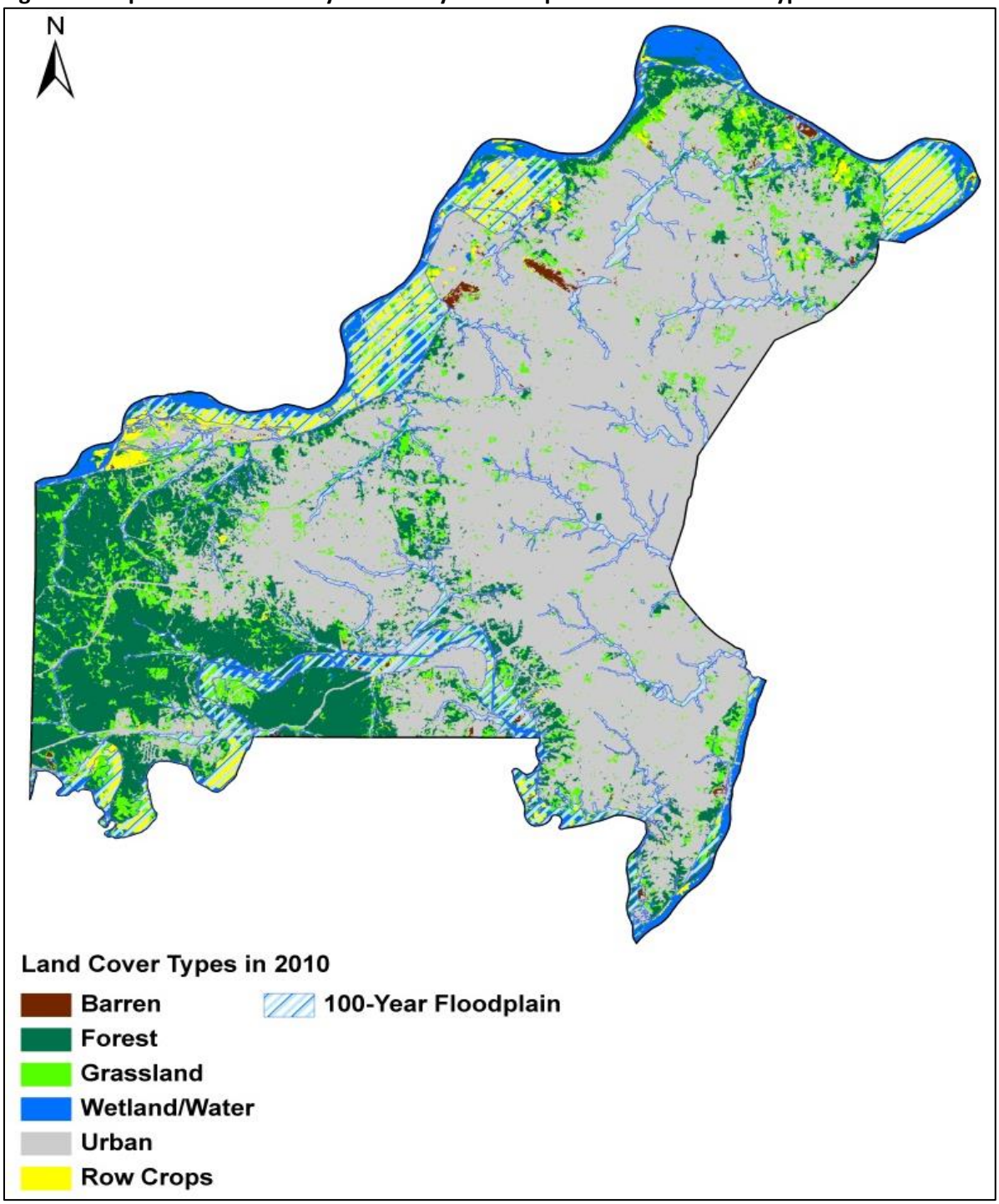
- Carolyn Kousky and Margaret Walls, “Floodplain Conservation as a Flood Mitigation Strategy: Examining Costs and Benefits,” *Ecological Economics* 104 (August) 2014, pp 119-128.
- Carolyn Kousky, Margaret Walls, and Ziyan Chu, “Measuring Resilience to Climate Change: The Benefits of Forest Conservation in the Floodplain,” *Proceedings of the Pinchot Institute Forest Conservation in the Anthropocene Conference*. U.S. Forest Service Pacific Southwest Research Station (peer reviewed). 2014.

Figure 1. Change in Meramec River Floodplain and Flood Depths in the 100-year Flood with a 50% Increase in Peak Discharges



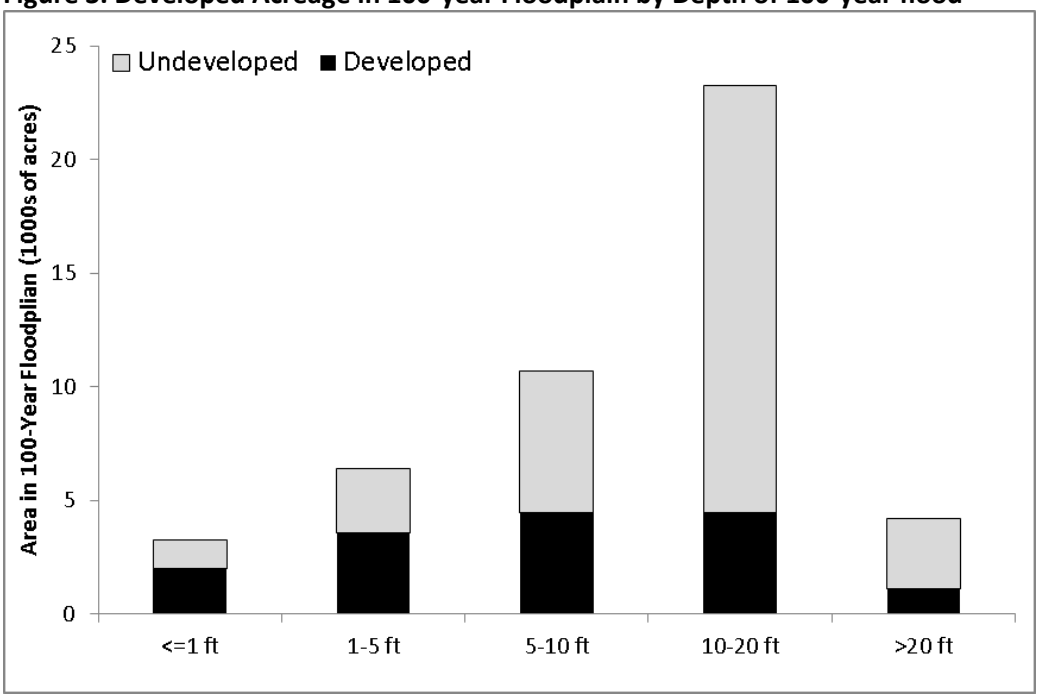
Source: Hazus flood modeling by Kousky, Walls, and Chu for project.

Figure 2. Map of St. Louis County with 100-year Floodplain and Land Cover Types



Source: Flood Modeling by Pinter and Remo for project, overlaid with land cover GIS layers from East-West Gateway.

Figure 3. Developed Acreage in 100-year Floodplain by Depth of 100-year flood



Source: Kousky, Walls, and Chu calculations for project based on Pinter-Remo flood modeling.

IV. Website Addresses

http://www.rff.org/centers/management_of_ecological_wealth/Pages/Land-Conservation-in-the-Floodplain.aspx

V. Any Additional Relevant Information

N/A